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TECHNICAL MEMORANDUM 2209

DEVELOPMENT TRENDS IN THE INCINERATION OF WASTE EXPLOSIVES AND PROPELLANTS

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PICATINNY ARSENAL
DOVER, NEW JERSEY

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DISPOSITION

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The following metric conversions, which conform to ASTM Standard E-380-74, Metric Practice Guide, are provided for the readers convenience.

Page No.	U. S.	Metric
4	1/8 in.	3.175 mm
	10 lb.	4.536 kg
	1600-1800°F	871-982°C
	125 ft.	38.1 m
11	550°F	288°C
	400 psi	2.75 x 10^3 kPa (kN/m^2)
	600-2200 psi	4.14-15.17 x 10^3 kPa
	400-600°F	204-316°C
15	6 in.	1.524 x 10^{-1} m
	9 ft.	2.74 m
	7 lb/hr	3.17 kg/hr
	.75 psi	5.17 x 10^3 Pa
	1.5 psi	10.34 x 10^3 Pa
	3.5 psi	24.13 x 10^3 Pa
	7.25 psi	49.98 x 10^3 Pa
	6 ft/sec	1.83 m/sec
	1650°F	899°C
	42 sq ft	3.9 m^2
	88 in.	2.24 m
	16,740 cfm	7.89 m^3/sec
	4,125 cfm	1.95 m^3/sec
	7.5 x 10^6 BTU/hr	2.19 x 10^3 W
	22,000 lb	9.98 x 10^3 kg
	1100°F	593°
	6.34 x 10^6 BTU	6.69 x 10^9 J
	7.2 x 10^6 BTU	7.59 x 10^9 J
	133 gal	5.03 x 10^{-1} m^3
19	47 lb	21.3 kg
	11 lb	4.99 kg
	21 lb	9.52 kg
	19 lb	8.62 kg
20	1600-1850°F	871-1010°C
	4.8-5.5 ft/sec	1.46-1.68 m/sec

A

Metric Conversions Cont.

Page No.	U. S.	Mult. by.	Metric
	For Fig. 13, the following conversion factors are to be used:		
23	psi	6.984×10^{3}	Pa
	°F	$\frac{5}{9}$ (°F-32°)	°C
	cfm	4.719×10^{-4}	m^3/sec
	lb/hr	4.536×10^{-1}	kg/hr
24	1500 cfm		7×10^{-1} m^3/sec
	150°F		66°C
	1650°F		899°C
	2.84×10^{6} BTU/hr		8.32×10^{5} W
	20.5 gal/hr		7.76×10^{-2} m^3/hr
	6.6×10^{6} BTU		6.963×10^{9} J
	18.1×10^{6} BTU		1.91×10^{10} J
	1100°F		593°C
	1650°F		899°C
	15 ft		4.572 m
	5 ft		1.524 m
	33 gal		1.25×10^{-1} m^3
	55 gal		2.08×10^{-1} m^3
25	250 lb/hr		1.134 kg/hr
	1000 lb/hr		4.536 kg/hr
	For Tables 1 & 2, the following conversion factors are to be used:		
27 & 28	\$/lb	4.535×10^{-1}kg	\$/kg
	lb/hr	4.535×10^{-1}kg	kg/hr
29	250 lb/hr		1.134 kg/hr
30	1000 lb/hr		4.536 kg/hr

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SUMMARY

The disposal of waste explosives and propellants has come under the close scrutiny of the E. P. A. since the ban on open burning.

In order to conform to current and proposed regulations, several incinerator systems were selected and either evaluated or are in the process of being evaluated. A few of these systems are: vertical induced draft, rotary kiln, Simplified Incineration Technique for Pollution Abatement (SITPA) I and II, wet air oxidation and fluidized bed incinerator.

The relative advantages and disadvantages of each system plus their process capabilities dictate their potential applications.

The current judgment by the Armament Command (ARMCOM) and other support organizations is that the SITPA II system is the most economically feasible system for use at LAP plants due to the low overall emissions. However, those applications, especially in P&E manufacturing plants, which have relatively high gaseous emissions will require a more sophisticated incinerator system (rotary kiln, fluidized bed) to meet anticipated air pollution standards.

INTRODUCTION AND BACKGROUND

In the manufacture, loading, assembly and packing of munition items, there are various non-usable wastes generated which must be disposed of in a sound ecological manner. This disposal has come under close scrutiny due to the EPA's (state and federal) regulations and the recent ban on open burning. The operation of these disposal facilities must be in accordance with both local and federal regulations. These regulations vary from one area to another according to the local air quality which depends on: a) geographic location, b) meteorological conditions, c) industrial proximity. d) pollution type and e) size of the community. An example of air quality regulations varying with geographical location is that certain midcentral United States areas have high non-urban particulate concentration standards of over 40 micrograms/cubic meter, while the northcentral portion of the United States may have particulate concentration standards of less than 10 micrograms/cubic meter. These boundary air quality standards as mentioned above are derived from the levels of pollution emissions as well as background concentrations due to the proximity of industrial air pollution contributors, vehicle density, residential heating and natural releases (swamps, mines).

The current practice of disposing of waste P&E by open burning is characterized by stockpiling of hazardous materials, air and water pollution, personnel exposure and inefficient combustion. In order to eliminate these problems and provide a reliable safe method of disposal, the various disposal methods described within this report were developed.

To completely appreciate the various methods of disposal, a brief description will be given of the general phenomenon involved in incineration.

All incinerators are concerned with the time that the waste is inclosed in the combustion chamber. The volume of the chamber should be large enough to contain the gas flow a sufficient time for the complete combustion of the solid waste and gaseous products. Perhaps the most important factor in combustion is the temperature. Heat is used as the driving force to sustain combustion. In many cases, it is desirable to have auxiliary fuel available to a) heat up the furnace, b) promote primary combustion when the waste does not contain adequate BTU content

for good combustion, c) provide secondary combustion for odor and smoke control, d) make available supplemental heat for heat recovery units. An additional factor in combustion is turbulence, provided by either baffles, constrictions or process design. The changes in direction and velocities thoroughly mix the products of combustion with the air (oxygen) necessary for combustion. Separation of combustion gases would occur if turbulence were not included in the design and under these conditions some of the gases would leave the chamber unburned. This would necessitate the use of an auxiliary burner, which would decrease process efficiency.

The provision of air for combustion is mandated for the complete combustion of waste products. One way that air is added to the incinerator is by natural draft through a chimney or stack. The higher the stack, the greater the amount of air that can be brought into the incinerator. Other ways of adding air are with fans that blow air into the incinerator (forced draft) or pull air through the incinerator (induced draft). Induced draft systems usually locate the fan between the incinerator and stack. In these cases, the hot gases must be cooled to protect the fan. Excess air may be added to the incinerator to insure complete combustion and regulate incinerator temperature. The excess air requirements differ for different types of waste having different compositions and BTU values.

The process of incineration can be described as a controlled, safe, efficient combustion process for burning P&E wastes to an inert residue. When P&E wastes are exposed to a turbulent atmosphere for a critical time period at an elevated temperature, combustion occurs. During combustion, moisture is evaporated, and the combustible portion of the waste oxidizes. Carbon dioxide, water vapor, ash and noncombustibles are the end products of incineration in addition to the heat generated.

ALTERNATIVE SOLUTIONS

The following incinerator systems (Fig 1) are all designed to handle the problem of waste P&E disposal and each attacks the problem in a different manner.

The more sophisticated P&E incinerators have been designed to meet air pollution standards (existing or forecasted) and provide adequate air and turbulence for proper combustion. Control equipment is included on some of these incinerators to further reduce the amount of CO, HC and NO_x released. Because of the quantity of NO_x emissions state and federal environmental agencies are identifying, assessing and promoting the development of cost-effective commercially viable methods for NO_x control from both existing and new stationary combustion sources. It is anticipated that controls will be required on all P&E waste incinerators and will take the form of lowering NO_x formation during combustion, post-combustion removal of NO_x from the combustion products or catalytic interaction within the process itself.

In addition, the majority of the incinerator systems require particle sizes of approximately 1/8" to obtain good combustion either in the dry state or for injection in an aqueous slurry. The P&E wastes are in the form of riser scrap, shell washout, process by-products and unacceptable end items. A large portion of this waste must be reduced prior to disposal. The current methods of reducing these wastes are by rotary knife grinders, cone crushers, attrition mills and ball milling. Each one of these methods uses a water overlay of approximately 10 pounds of water for each pound of P&E waste. The water overlay keeps the grinding area cool to prevent the P&E waste from heating up and also helps reduce the possibility of spark formation. It also helps make plastic-type propellant more rigid and therefore easier to grind.

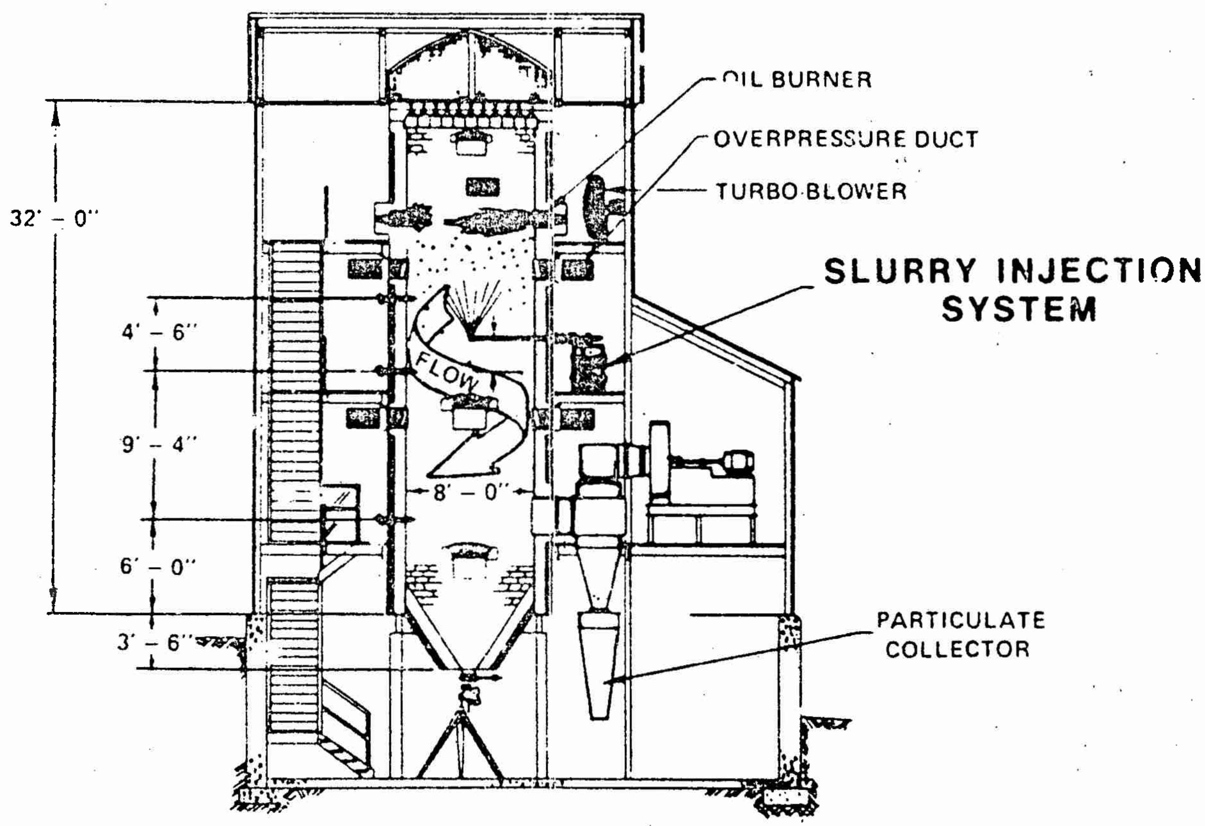
Vertical Draft Incinerator—The forerunner of the P&E waste incinerator program is the vertical draft incinerator (Fig 2). This incinerator was constructed in the 1950's at Picatinny Arsenal to dispose of red water and other contaminated liquid wastes. The unit is a cylindrical steel furnace lined with firebrick. It was modified to dispose of waste P&E in aqueous slurries of 25% by weight. Feasibility and safety requirements, particle size reduction, suspension, injection, combustion and baseline gaseous emissions data were established and evaluated. The process consisted of heating the chamber by means of three oil-fired

INCINERATION TECHNIQUES

- VERTICAL, INDUCED DRAFT
- ROTARY KILN
- SITPA I & II

  (**S**IMPLIFIED **I**NCINERATION **T**ECHNIQUE FOR **P**OLLUTION **A**BATEMENT)
- WET AIR OXIDATION
- FLUIDIZED BED

FIGURE 1.



PICATINNY ARSENAL-VERTICAL INDUCED DRAFT INCINERATOR

FIGURE 2.

burners to a temperature of 1600—1800°F and then injecting the slurry up toward the flame. The downward draft provided by the induced draft enhanced the combustion process by providing combustion air and circulated the gaseous products within the combustion chamber. The gaseous products were then passed through a cyclone separator and then vented to the atmosphere through a 125' stack. This type of incinerator is presently outdated due to its inefficient operation and poor emission control.

Rotary Kiln—The rotary kiln incinerator (Fig. 3) consists of a refractory lined cylinder slightly inclined to the horizontal at an angle usually between 2—5° and rotating at a slow speed (1—5 rpm). Often both the speed of rotation and the inclination of the furnace are variable so that the flow of material through the cylinder and the retention time for combustion can be controlled. Afterburning facilities can be incorporated in a separate auxiliary chamber, and the equipment generally lends itself to flexible plant layout. By rotation, these furnaces offer the advantages of a gentle and continuous mixing of the P&E slurry, but capital and maintenance costs are high. These costs are derived from the mechanical design requirements of both rigidity of the cylinder and close tolerances for the roller path drive as well as the high-temperature seals between fixed and moving parts. Another major disadvantage is the adverse effect of the explosive slurry contacting the refractory lining at elevated temperatures and the detrimental effect on the refractory of cooling and reheating the chamber during shutdowns.

This system requires the use of a cooler and scrubber to reduce the gaseous and particulate emissions and exhaust gas temperature prior to the exhaust fan and stack.

SITPA I—The Simplified Incineration Technique for Pollution Abatement (SITPA) is an incinerator designed to eliminate the complexity of the other systems described (Fig. 4). The SITPA process involves manually placing P&E waste on a concrete pad or covered ditch and remotely igniting it. The pad has a hood which accepts the combustion gases and draws them into a duct by means of induction fans. The duct is connected to a baghouse which removes particulate matter from the exhaust gases. The gases pass through the fan and then out the stack. It is possible to hook up several pads to a single baghouse by ducts and a manifold.

The system, while simple, does not provide either the process control, pollution abatement or safety features inherent in the other systems described.

ROTARY KILN INCINERATOR

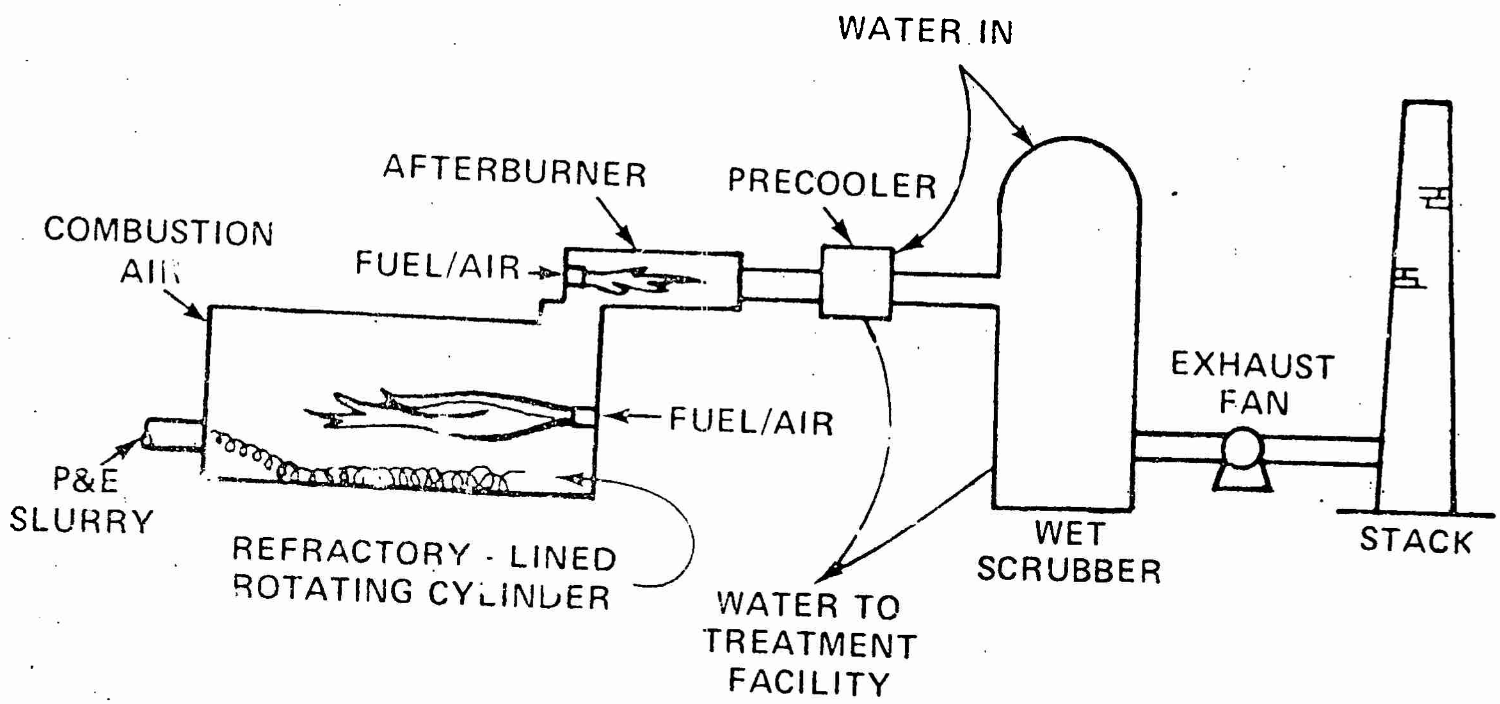


FIGURE 3.

SITPA I SYSTEM

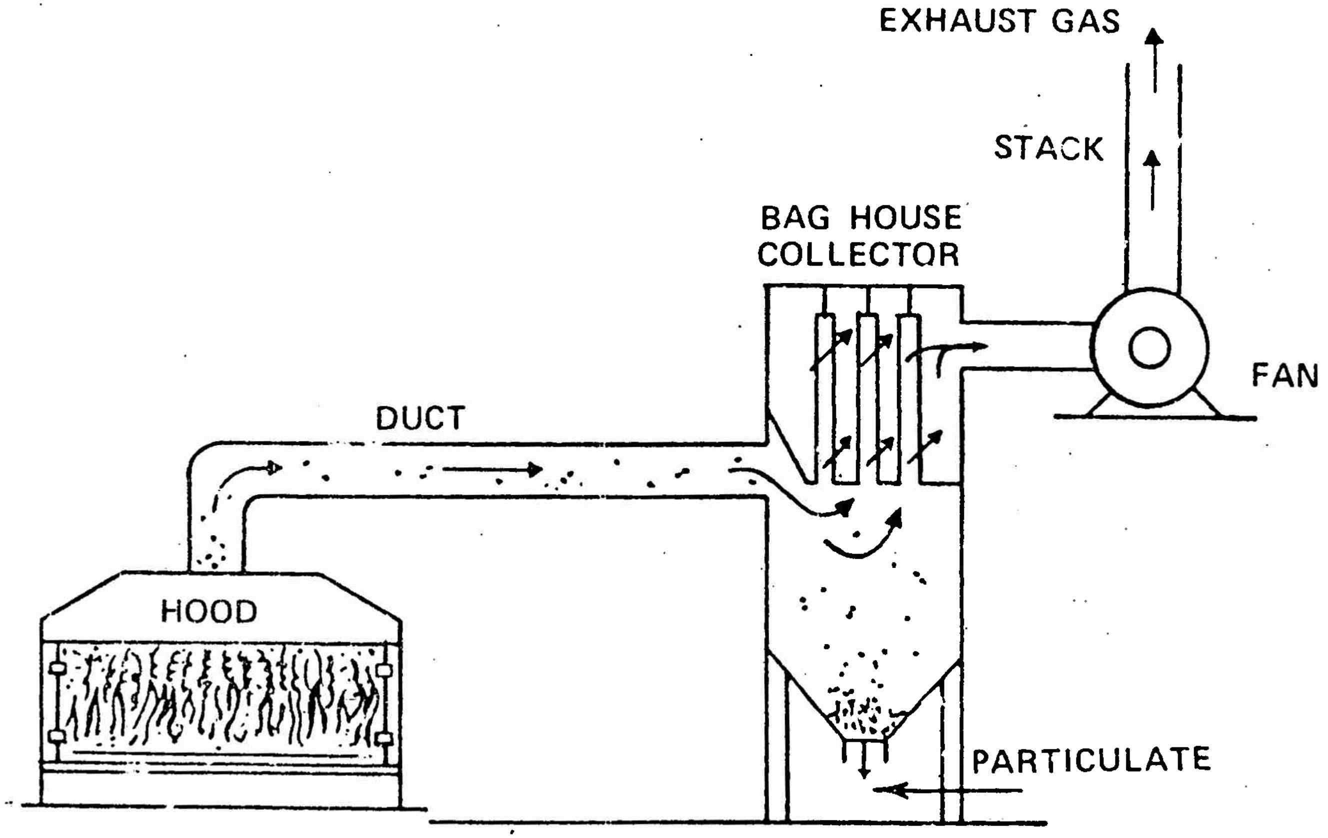


FIGURE 4.

SITPA II—The SITPA II (Fig. 5) process is a specially designed unlined rotary kiln incinerator into which the waste P&E is fed into the combustion chamber in cans, containing set amounts of the waste P&E, placed at intervals on a conveyor belt. The waste P&E is burned in the combustion chamber, which is heated by oil burners, and the combustion gases are removed from the chamber by an induction fan and then passed through a baghouse to remove particulates. This system could be operated in the semi-continuous mode for long periods of time.

fuel intensive

Wet Air Oxidation—This process is fundamentally the aqueous oxidation of waste P&E in a high pressure vessel (autoclave) (Fig. 6). The vessel and the water inside are initially heated to 550°F and 400 psi by steam and compressed air. When these conditions are reached, the steam is shut off and the feed started. The ground waste P&E is fed in a continuous aqueous slurry along with compressed air. The P&E wastes are oxidized and the BTU content of the waste is sufficient to sustain the reaction without any supplemental heat inputs. The vessel is operated typically at pressures in the range of 600-2200 psi and at temperatures between 400 and 600°F. The oxidation products, consisting of gaseous and liquid oxidation products, nitrogen from the compressed air, and a minor quantity of ash, are cooled by the feed stream in a heat exchanger and separated into a gaseous and a liquid stream.

The gaseous stream is treated by an afterburner to destroy CO and residual hydrocarbons, and a wet scrubber is used to remove NO_x prior to discharge to the atmosphere. The liquid phase is further processed to remove acidity and metallic salts, and the purified water recycled to the slurry-preparation stage.

Fluidized Bed Incinerator—The fluidized bed incinerator (Fig. 7) is a simple and compact system using aluminum oxide (alumina) for the bed material. If large solid grains or chunks of P&E waste are to be disposed of, they must be size reduced prior to being introduced in an aqueous slurry (35% by weight). The operation of the fluidized bed involves the forcing of air through the distributor plate which can be controlled to a desired rate. At low rates, the bed remains in its original "settled" state with the pressure drop across the bed increasing with the flow rate, until it is equal to the downward force exerted by the bed material resting on the plate. The bed begins to expand at this point which is called "incipient fluidization," allowing more gas to pass through the bed at the same pressure drop. The bed is now fluidized and has all the properties of a fluid.

SITPA II SYSTEM

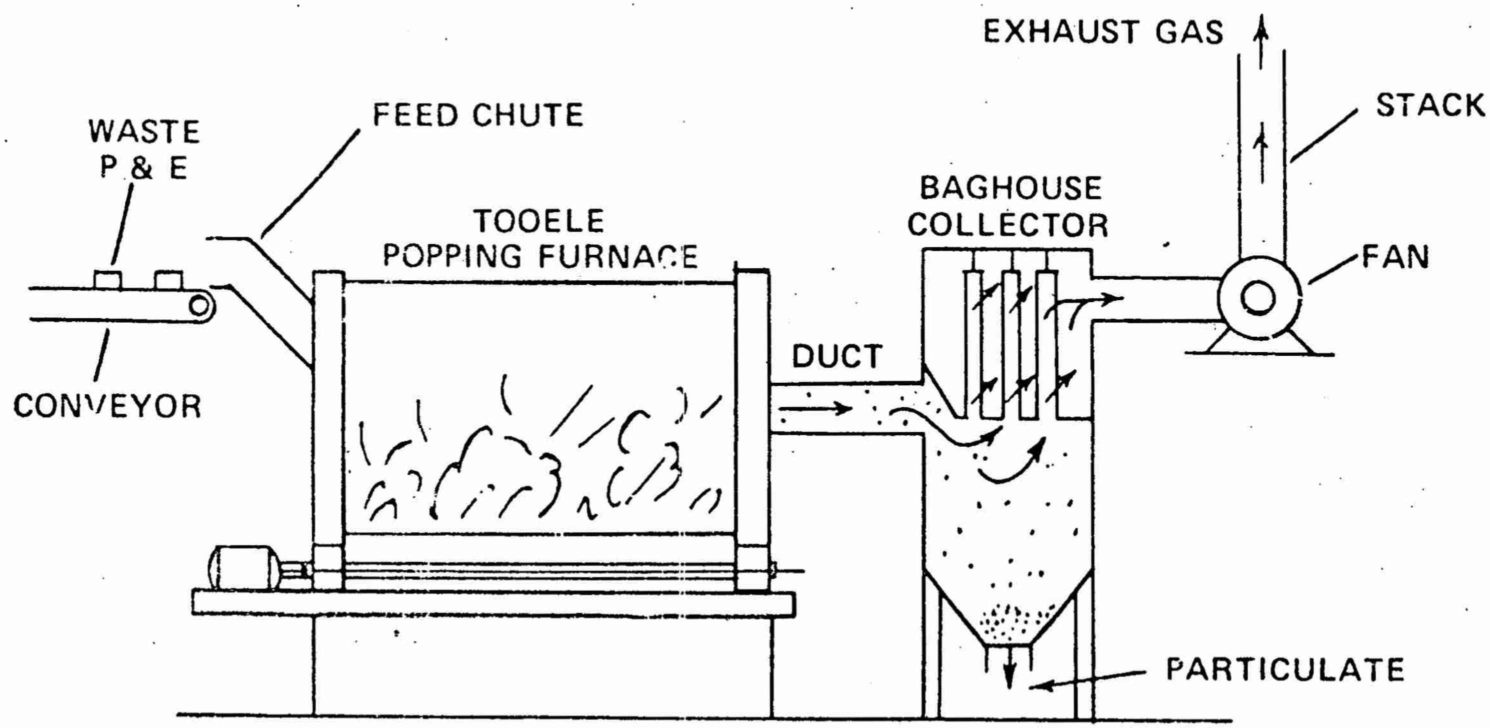


FIGURE 5.

WET-AIR OXIDATION (ZIMPRO) PROCESS

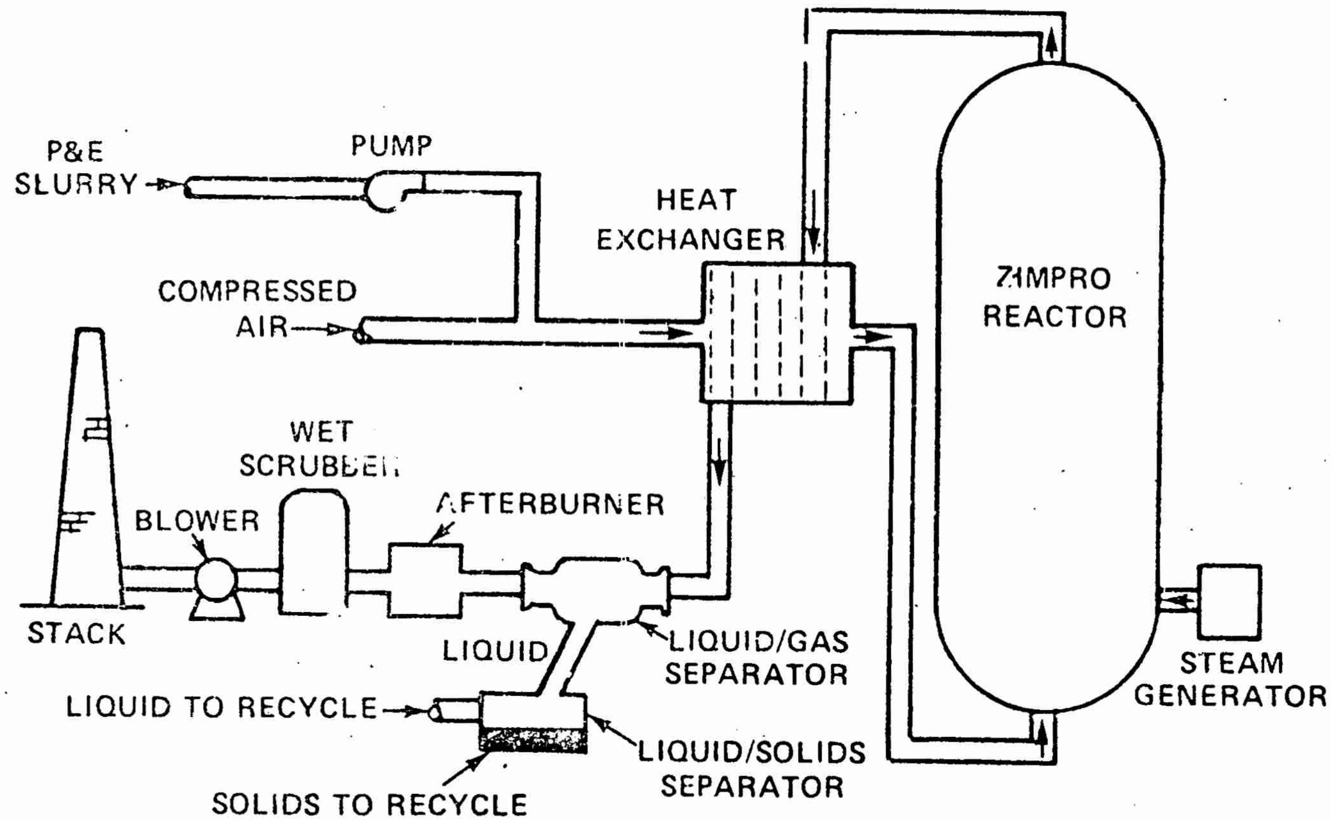


FIGURE 6.

FLUIDIZED BED CONVERSION PA INCINERATOR

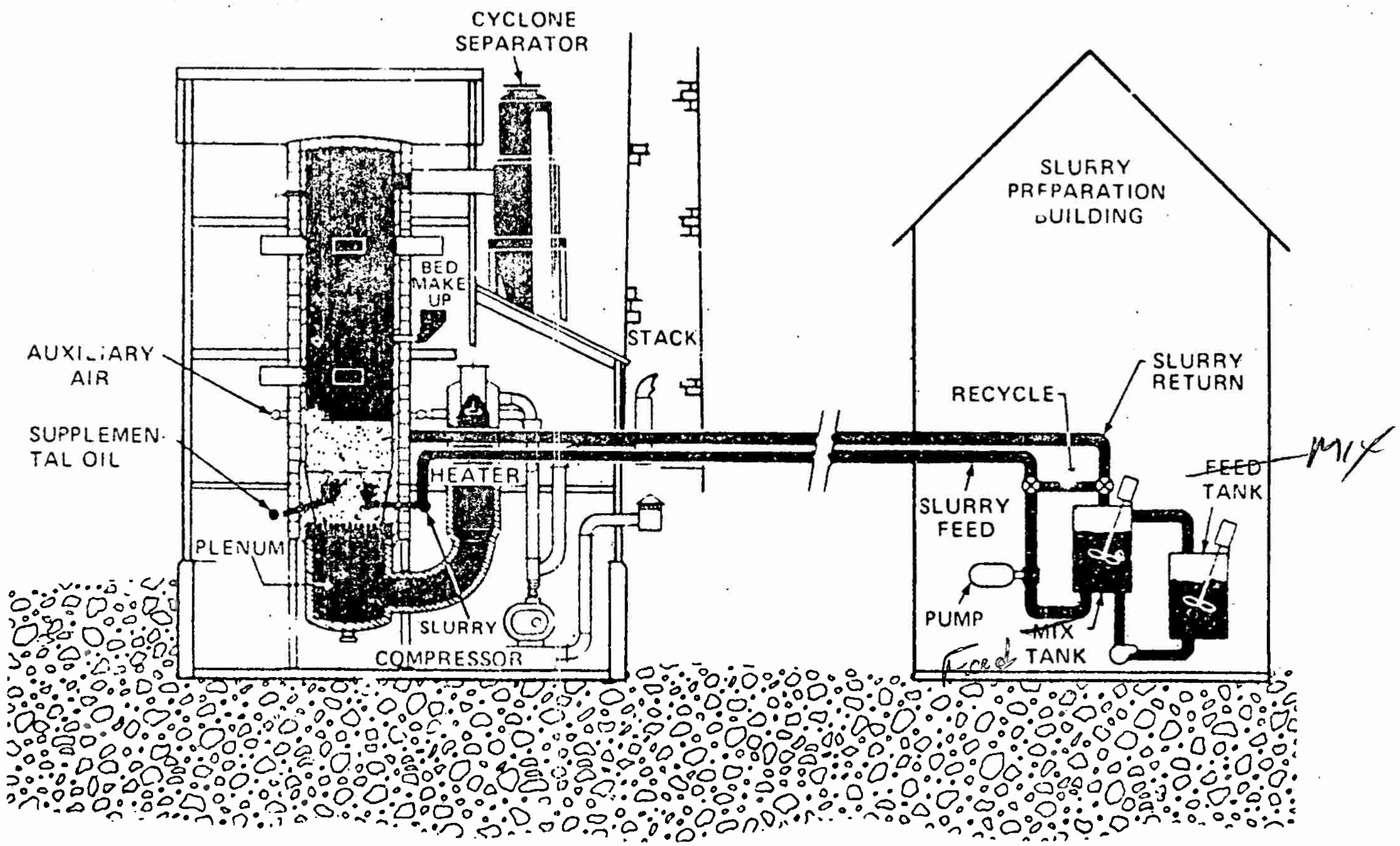


FIGURE 7.

The advantages of this system are: the enriched oxygen of the bed coupled with the mixing action of the alumina and waste ensures complete combustion, minimizing carbon monoxide and hydrocarbon emissions; the uniform temperature of the bed plus the use of a nickel catalyst limits the formation of nitrogen oxides. The fluidized bed has provisions for the injection of supplemental oil and auxiliary air into the bed. The effects of the supplemental oil were discussed earlier and the effects of the auxiliary air will now be discussed.

Combustion is a chemical reaction that requires the contacting of a fuel with oxygen at a temperature above the kindling temperature. Both a high degree of turbulence and adequate oxygen are required to attain complete combustion. Excess air is the amount of air added to a combustion process beyond that required stoichiometrically by the chemical reaction. The auxiliary air nozzles provide excess air to the bed to help reduce noxious gaseous emissions. The bed itself maintains a reducing atmosphere while the auxiliary air helps provide an oxidizing atmosphere in the upper portion of the bed. The nitrogen present in the combustion reactions can come from both the air and the fuel. Some of the nitrogen is oxidized, with nitric oxides (NO_X) being an undesirable product of combustion. The NO_X formed is a function of the combustion temperature, reaction rates, residence time, nitrogen and oxygen concentrations and quench rates. As excess air and turbulence in the fluidized bed chamber are increased, more products of complete combustion are obtained. These products are further reduced by the presence of the nickel oxide catalyst in the bed which drastically reduces the NO_X concentration in the exhaust gases.

EVALUATION OF VARIOUS CONCEPTS

The current judgment by the Armament Command (ARMCOM) and other support organizations is that the SITPA II System is the most cost effective system based on present emission standards (Fig. 8). This is especially true for LAP plants that have low overall gaseous emissions due to minimal in-plant industrial operations. In addition, most of the LAP plants are in remote locations, away from any large cities, and therefore have standards that are less stringent.

However, ARMCOM is convinced that future standards will be stricter especially in the area of NO_x emissions. This will place an added burden on the P&E manufacturing plants that manufacture acids and use these acids in their production processes. Therefore, the P&E manufacturing plants have relatively high gaseous emissions due to the nature of the work. Furthermore, most of these plants are located near industrial cities because of their requirements for raw materials. This means that there probably will be more restrictions on these plants as to the quantities of pollutants emitted, including P&E incinerator emissions. Thus, if a plant requires a P&E incinerator having the capability of sustained, multiyear operation with minimal pollution, the fluidized bed incinerator would be the most cost effective system, see Economic Analysis, page 25.

SUMMARY

INCINERATOR	ABATEMENT		COST
	PARTICULATES 0.1 GR/SCF	NO_x 200 PPM	(CAPITAL & OPERATING)
VERTICAL ID	YES	NO	NA (FEASIBILITY DEMO ONLY)
ROTARY KILN	YES	MARGINAL	HIGH (LOW COMB EFF SCRUBBER WATER TREAT)
SITPA I	YES	NO	LOW (NO FUEL; NO NO_x ABATEMENT; MANUAL, BATCH OPER)
SITPA II	YES	NO	LOW (FUELOIL; NO NO_x ABATEMENT, MANUAL, BATCH OPER)
WET AIR OXID	YES	YES	MEDIUM (NO FUEL; PROCESS & SCRUBBER WATER TREATMENT)
FLUIDIZED BED	YES	YES	MEDIUM (HIGH COMB EFF; NO SCRUBBER WATER TREAT)

FIGURE 8.

DEVELOPMENT OF FLUIDIZED BED INCINERATOR

The current design of the fluidized bed incinerator pilot plant evolved from a small pilot plant evaluation performed under a contractor support effort. Picatinny, in addition to having the responsibility for the overall control of the P&E incinerator project, was obligated to select and develop an improved incineration system for future use. A study was performed and it was concluded that the fluidized bed incinerator was the best system to meet the future needs of the Army. The system selected for investigative studies (Fig. 9) was six inches in diameter and nine feet high and had a feed rate of seven lbs/hr of dry explosives. This fluidized bed incinerator was designed to accept a solid/water slurry feed and the bed itself was sized such that it could be fluidized with approximately 50% of the anticipated requirement of 120% of stoichiometric air. The importance of this fact is that it improved the flexibility of the incinerator in that it allowed for the operation of the system in either a one or two stage combustion mode, i.e. all the air is fed into the bottom of the bed or part of the air is fed into the bottom and part is fed into the upper portion of the bed, respectively.

In addition to the incinerator, the system included a slurry feed system, cyclone particulate collector and stack gas analyzer. The slurry feed system was similar to the ones utilized above having a mix/feed tank with a large recirculation line and the incinerator feed is tapped from this line and fed into the incinerator through a metering pump. The cyclone collector removed any particulates from the exhaust gas before the gas was analyzed for NO, NO_x, CO, CO_2, HC, and O_2.

A series of 37 test runs were made in which the bed temperature, air velocity and feed rate and types of waste materials were varied (Fig. 10). Runs were made both in one stage and two stage modes at durations of up to six hours. The incinerator operated effectively in disposing of the explosives and propellants; however, the emission levels of 640 ppm - NO_x, 650 ppm - CO and 350 ppm - HC were well above the 200 ppm goal for each of these pollutants and were approximately equal to the untreated emissions from the rotary kiln and vertical incinerators. At this point in the test program, it was decided to try a catalyst in the bed. After some preliminary testing, nickel oxide was selected for use in the fluidized bed. An addition of 6% (by weight) of nickel oxide to the alumina bed (Al_2O_3) caused a spectacular reduction in the emissions from the incinerator: 57 ppm - NO_x, 40 ppm - CO, 10 ppm - HC (Fig. 11).

The results of this program led to the decision to convert the Picatinny Arsenal vertical incinerator to a fluidized bed incinerator. Some of the

LAB SCALE FLUIDIZED BED COMBUSTOR

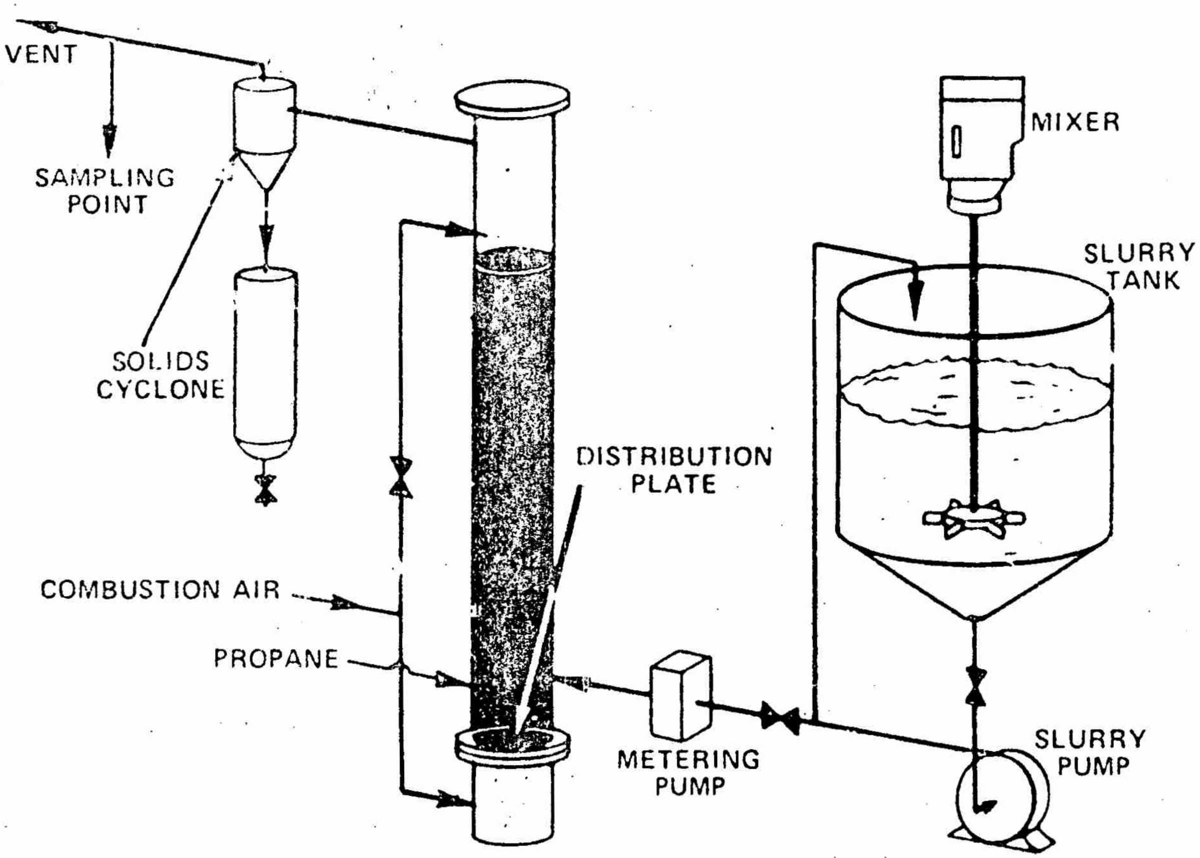


FIGURE 9.

SUMMARY OF FLUIDIZED BED TEST PROGRAM

MATERIAL	NO. OF TESTS	TOTAL DURATION (HRS)	QUANTITY BURNED (LBS)
TNT	16	60	47
COMP B	2	12	11
RDX	6	20	21
HMX	7	24	19
NH_4NO_3	1	6	--
HNO_3	1	6	--
CBI (98%NC)	4	22	19

FIGURE 10.

FLUIDIZED BED INCINERATOR

TYPICAL COMBUSTION EMISSION DATA

Fuel rates?

PARAMETERS

- TEMPERATURE: 1600 – 1850° F
- FEED RATE: 7 LB/HR 10% TNT/WATER SLURRY
- VELOCITY: 4.8 – 5.5 FT/SEC
- THEORETICAL AIR

	1 STAGE	2 STAGE
PRIMARY	120%	63%
SECONDARY		57%

	CATALYTIC	NON CATALYTIC
NO (ppm)	47	800
NO_x (ppm)	57	840
CC (ppm)	40	650
HC (ppm)	10	350
CO_2%	12	12
O_2%	3.7	4.0

FIGURE 11

major components designed were the preheater, plenum, injection nozzles, air distribution grid and blower.

The schematic diagram used to determine design operating conditions is shown in Fig. 12. Various parameters were determined from air, fuel and explosive slurry entry stations to the final discharge from the combustion chamber which leads into the cyclone separator used to remove any residual particulates. Fig. 1[illegible] lists the various key design parameters determined by assumption or by calculation.

Blower Design Capacity— Procedure for determining the design capacity for a major component, the blower system, was found by estimating system pressure drops as follows:

Preheater	0.75 psig
Grid	1.50
Bed	3.50
Cyclone	1.50
Total	7.25 psig

Calculation of blower capacity was made for a maximum gas velocity of 6 ft/sec in the stack, maximum chamber temperature of 1650°F, chamber pressure of 1.5 psig and inside chamber cross-sectional area of 42 sq. ft. (88 inch dia.). The cfm thus determined was 16,[illegible]40 cfm which when related to standard conditions becomes 4125 scfm.

For a pressure buildup of 7.25 psi and a capacity of 4125 scfm across the blower, the design HP would be 130.5; however, considering future needs of scrubbing equipment to accommodate perchlorate propellants and any ensuing additional pressure losses, the blower design horsepower was increased to 250.

Start-Up Fuel Requirement—The preheater was designed to yield 7.5×10^6 BTU/hr. The heat required to heat a cold bed (22,000 lbs alumina) to 1100°F is 6.34×10^6 BTU. The heat required to heat insulated walls in the vicinity of the bed was found to be 7.2×10^6 BTU. Therefore, it takes 2-1/2 hrs to bring the system up to initial temperature (1100°F) while consuming 133 gallons of No. 2 fuel oil. At this point, the preheater may be shut off and fuel injected directly into the bed to maintain the combustion chamber temperature at 1050°F under equilibrium conditions. The calculations include sensible heat losses required for fuel oil combustion.

$\frac{133 \text{ gal}}{2\frac{1}{2} \text{ HRS}}$

$\frac{53.2 \text{ gal}}{\text{HR}}$ start up

SCHEMATIC DIAGRAM FOR DETERMINING DESIGN OPERATING CONDITIONS

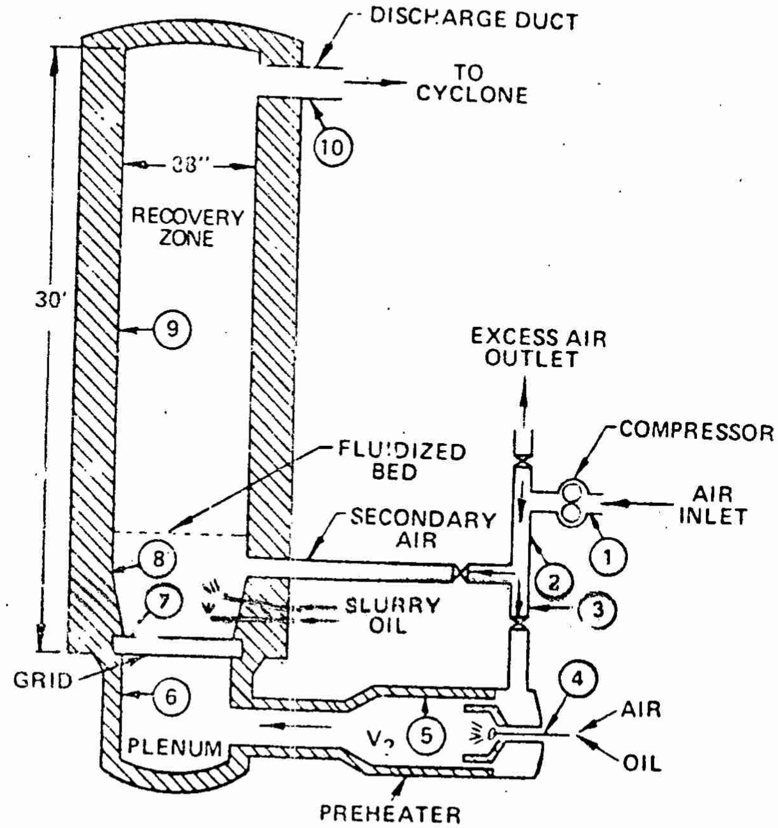


FIGURE 12.

KEY DESIGN PARAMETERS

10% TNT/SLURRY WEIGHT RATIO

	STATIONS	T_a	$P_{a(s)}$	V_a	$W_{o(s)}$	
1	COMPRESSOR INLET	amb	amb	5,800		
2	COMPRESSOR OUTLET	150	6.0	5,000		
3	FLUIDIZING AIR FEED	150	6.0	2,180		
4	PREHEATER OIL/AIR INLET	150	6.0	20	165	#/HR 165 preheat 23 gph
5	PREHEATER CHAMBER	1100	6.0	4,650		
6	PLENUM	1100	6.0	4,650		
7	TOP OF GRID	1100	4.7	4,650		
8	IN FLUIDIZED BED	1650	3.0 (5.0)	8,000	522 (4800)	#/HR 522 / 687 #/hr operating 72 gph
9	RECOVERY ZONE	1650	3.0	15,200		
10	DISCHARGE DUCT	1600	1.5" H_2O	15,200		

Startup period 95 gph

LEGEND

T - TEMPERATURE - °F

P - PRESSURE - PSIG

V - VOLUMETRIC FLOW RATE - SCFM

W - WEIGHT FLOW RATE - LBS/HR

a - AIR

o - OIL

s - w/SLURRY

ASSUMED: T_a @ STA 8

P_a @ STA 6

V_a @ STA 2

FIGURE 13.

Sustaining Fuel Requirement—A 25 percent by weight ratio of slurried TNT in water is in theory self sustaining. That is, enough heat is liberated from the TNT to evaporate the water. Therefore, the sustaining fuel only has to heat the incoming air to the plenum (1500 cfm) from [illegible] to 1650°F and accommodate system heat losses estimated as 10%. This results in a heat requirement of 2.84×10^6 BTU/hr which amounts to 20.5 gals/hr of No. 2 fuel oil.

System Heat Retention During Shutdown—The calculated heat loss from the system, during the 16 hour shutdown period, is 6.6×10^6 BTU. This is derived from the heat loss through the ceramic (mostly alumina-silica) wall material of 5.5×10^6 BTU plus an allowance of 20% (1.1×10^6 BTU) for radiation and stack losses. The heat retained in the incinerator system is 18.1×10^6 BTU. From the relationship for heat content

$$\frac{\Delta h_1}{\Delta h_2} = \frac{\Delta T_1}{\Delta T_2}$$

$$\frac{\text{heat in bed}}{\text{heat loss}} = \frac{18.1 \times 10^6}{6.6 \times 10^6} = \frac{1650° - 70°}{1650° - T_2}$$

Start temperature, $T_2 = 1100°F$

The above temperature is possible after 16 hours of shutdown because of the good wall insulating properties, the good heat retention capability of the bed material, and the large heat sink the settled bed provides ([illegible] lbs of alumina).

Further, it can be shown that the quantity of fuel required to bring the bed up to operating temperature, following this shutdown period, is only a fraction of the 133 gallons of fuel oil needed for a "cold" start-up. The energy required to reheat the alumina bed and incinerator wall (15 feet high—corresponding to expanded bed height plus 5 feet) to 1650°F is equal to 4.6×10^6 BTU or 33.0 gallons of fuel oil. Since the oil feed capacity of the preheater is 55 gallon./hr, it would take only 45 minutes to bring the bed up to temperature.

ECONOMIC ANALYSIS

In the evaluation of alternate systems, it is necessary to consider the economic factors associated with each system. The economic analysis of the fluidized bed incinerator vs the rotary kiln incinerator was performed by the Mobility Equipment Research and Development Command (MERDC) under the direction of Picatinny Arsenal. The method utilized by MERDC to perform this analysis is the present value unit cost (PVUC) method, which complies with AR 37-13.

This method utilizes a computerized mathematical model to economically evaluate alternate incinerator designs. The model considers capital costs, operating costs, time horizons, depreciation, interest and other related factors (Fig. 14). The output yields the PVUC per pound of material incinerated. The PVUC program was used to evaluate the cost parameters of the fluidized bed vs the rotary kiln over various time horizons and load (operating) rates. The data generated from two typical runs (250 and 1000 lbs/hr) are shown in Tables 1 and 2 and Figs. 15 and 16. The TNT/slurry weight ratio was 25 percent for these calculations.

By inspection of the Tables, it can be seen that the cost saving that can be realized using the fluidized bed incinerator varies from $19,000/yr up to $193,000/yr with a 250 lb/hr capacity and from $108,000/yr to $311,000/yr with a 1000 lb/hr capacity. The major cost saving attributed to the fluidized bed when compared to the rotary kiln is due to the lower operating costs (fuel usage). ?

The PVUC model can be used to evaluate any number of alternative designs provided sufficient operating data is available. For example, listings of required cost parameters for the evaluation of the different incinerator systems are shown in Fig 17. By utilizing this program, sufficient economic data is generated to provide management with a viable decision making tool when choosing between various process alternatives.

ECONOMIC ANALYSIS FACTORS

DESIGN CAPACITY

OPERATING CAPACITY

TIME HORIZONS (5, 10, 15, 20, 25 YRS)

CAPITAL EQUIPMENT:

- ECONOMIC LIFE - 25 YRS
- DEPRECIATION RATE - STRAIGHT LINE
- INTEREST - 10%
- SALVAGE VALUE

OPERATING COSTS

FIGURE 14.

TABLE 1

COST FACTORS FOR THE 250 LB/HR CASE

Yr	Design Capacity (#/hr)	Oper. Rate (%)	Quan. Burned (#/day)	Oper. Schedule	Rotary Kiln Oper. Cost ($/day)	Fluid Bed Oper. Cost ($/day)	PVUC Rotary Kiln $/# Expl	PVUC Fluid Bed $/# Expl.	Cost Savings $/day	Cost Savings $/yr*
5	250	33	2000	1/8/5	276.19	141.43	.26358	.22520	76.76	19,190.
10							.25633	.21022	80.08	20,020.
15							.25046	.20803	82.80	20,700.
20							.24581	.20333	84.96	21,240.
25							.24222	.19891	86.62	21,655.
5	250	66	4000	2/8/5	567.03	255.09	.20450	.14102	253.92	63,480.
10							.20088	.13656	257.28	64,320.
15							.19794	.13294	260.00	65,000.
20							.19562	.13008	262.16	65,540.
25							.19382	.12787	263.80	65,950.
5	250	100	6000	3/8/5	1027.63	1728 ~~347.76~~	.21310	.10946	621.84	155,460.
10							.21068	.10649	625.14	156,285.
15							.20873	.10407	627.96	156,990.
20							.20718	.10217	630.06	157,515.
25							.20598	.10069	631.74	157,935.
5	250	100	6000	3/8/6 MOB	1027.63	344.73	.20479	.09872	636.42	190,928.
10							.20285	.09634	639.06	191,718.
15							.20128	.09441	641.22	192,366.
20							.20004	.09288	642.96	192,888.
25							.19903	.09170	644.28	193,284.

*250 days - (Standard Work Week)
300 days - (MOB - 6 Day Work Week)

Capital Equipment Cost FBI - $582,000
RK - $472,000

Current Year Dollars - FY74 Base

TABLE 2

COST FACTORS FOR THE 1000 LB/HR CASE

Yr	Design Capacity (#/hr)	Oper. Rate (%)	Quan. Burned (#/day)	Oper. Schedule	Rotary Kiln Oper. Cost ($/day)	Fluid Bed Oper. Cost ($/day)	PVUC Rotary Kiln $/# Expl	PVUC Fluid Bed $/# Expl.	Cost Savings $/day	Cost Savings $/yr*
5	1000	33	8,000	1/8/5	815.20	282.12	.14212	.08784	434.24	108,560.
10							.13950	.08481	439.92	109,980.
15							.13792	.08235	444.56	111,140.
20							.13643	.08040	448.24	112,060.
25							.13528	.07889	451.12	112,780.
5	1000	66	16,000	2/8/5	1165.49	459.05	.09296	.05498	607.68	151,920.
10							.09179	.05346	613.28	153,320.
15							.09085	.05223	617.92	154,480.
20							.09011	.05126	621.60	155,400.
25							.08953	.05050	624.48	156,120.
5	1000	100	24,000	3/8/5	1649.51	554.51	.08214	.04063	996.24	249,060.
10							.08136	.03962	1,001.76	250,440.
15							.08074	.03880	1,006.56	251,640.
20							.08024	.03815	1,010.16	252,540.
25							.07985	.03765	1,012.80	253,200.
5	1000	100	24,000	3/8/6 MOB	1649.51	548.63	.07947	.03690	1,021.68	306,504.
10							.07885	.03600	1,026.24	307,872.
15							.07835	.03543	1,030.08	309,024.
20							.07795	.03491	1,032.96	309,888.
25							.07765	.03451	1,035.36	310,608.

*250 days - (Standard Work Week)
300 days - (MOB - 6 Day Work Week)

Capital Equipment Cost: FBI - $792,000
RK - $606,000

Current Year Dollars - FY 74 Base

COMPARISON OF OPERATING COSTS (250#/HR)

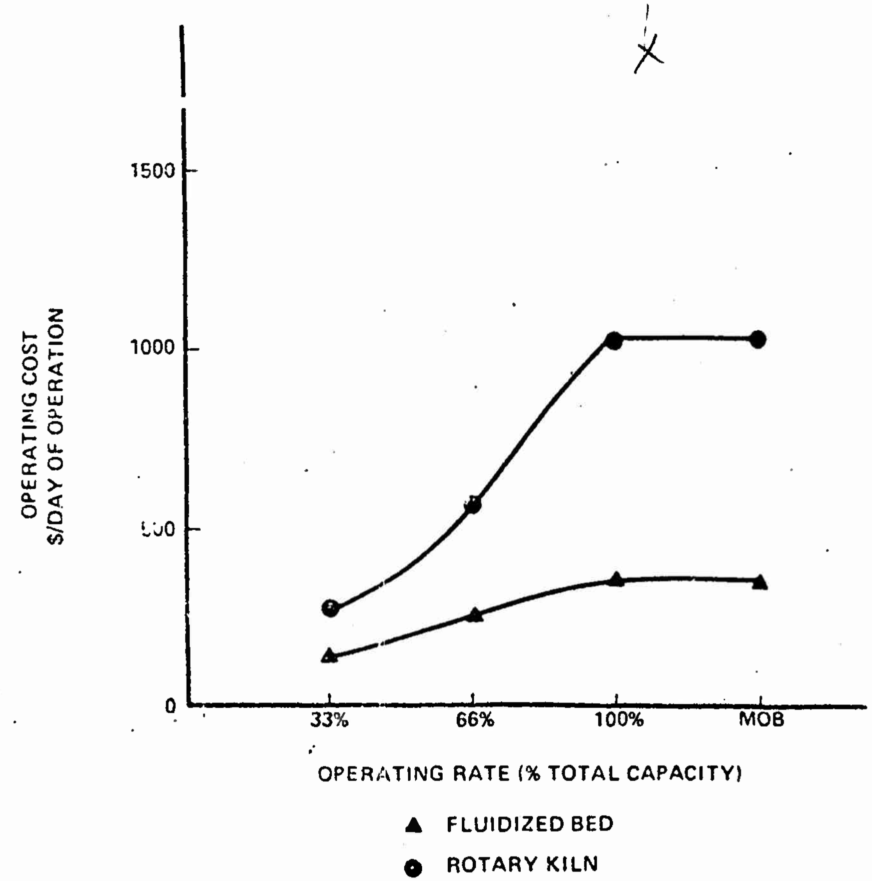
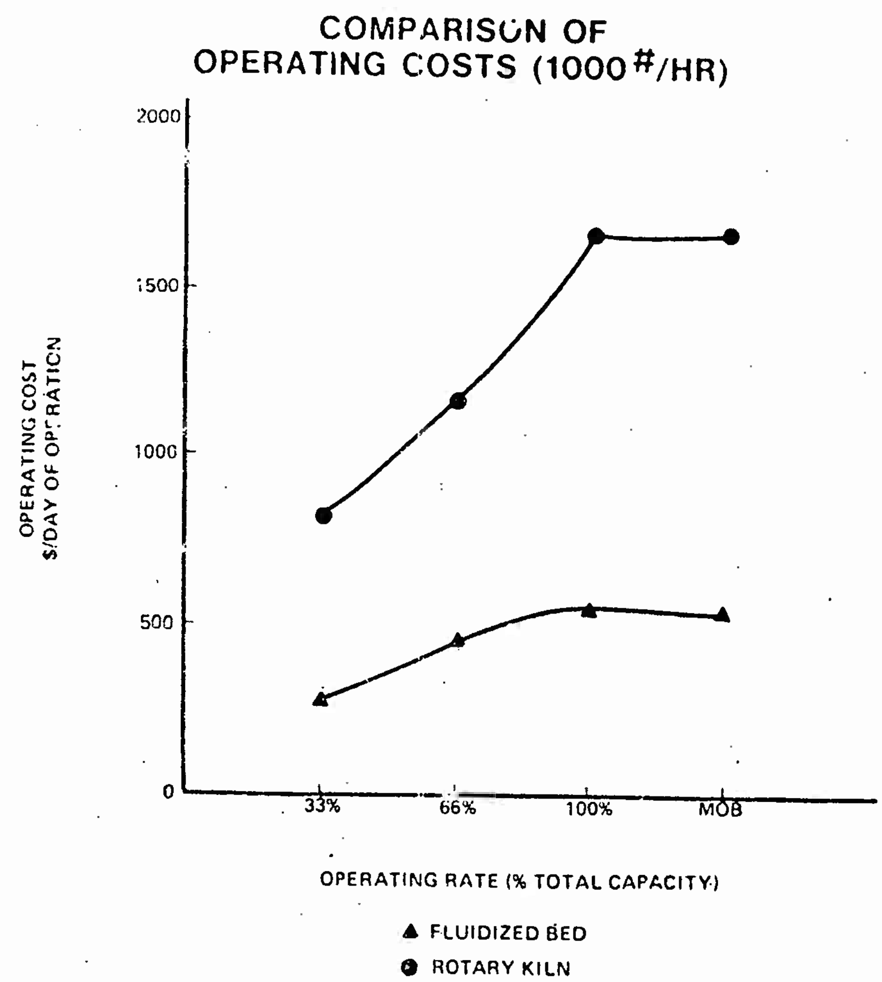


FIGURE 15.



COMPARISUN OF
OPERATING COSTS (1000#/HR)
2000
1500
1000
500
0
OPERATING COST
$/DAY OF OPERATION
33%
66%
100%
MOB
OPERATING RATE (% TOTAL CAPACITY)
FLUIDIZED BED
ROTARY KILN

FIGURE 16.

FACTORS FOR PVUC ECONOMIC ANALYSIS

(AR 37-13)

- PREPARATION LABOR COSTS OVER OTHER SYSTEMS (FLUID BED, ROTARY KILN)
- LABOR DURING DOWNTIME
- NO. OF BURNS AND QUANTITY DISPOSED OF PER DAY (8 HR. SHIFT)
- RAW MATERIALS (INCL REPLACEMENT PARTS)
- UTILITIES
- LIFE CYCLE OF EQUIPMENT
- EQUIPMENT COSTS

OTHER DECISION MAKING COST FACTORS

- P & E PREPARATION - MOTOR/GRINDER, FEED MECHANISM, WATER, DEWATERING SYSTEM, DRYER.
- SITE PREPARATION - ACCESS ROADS, ELECTRICAL POWER, WATER, COMPRESSED AIR, SANITARY SEWERS, LIGHTING, TELEPHONE, DRAINAGE.

FIGURE 17.

CONCLUSIONS

a. The vertical draft incinerator being the forerunner of the incinerator program displayed the feasibility and safety in the incineration of P&E wastes. This system is presently outdated due to its inefficient operation and poor emission control.

b. The rotary kiln incinerator demonstrated its capability by safely disposing of a wide variety of P&E wastes during the evaluation program. The system offers flexibility, good process control, average combustion efficiency and, with a scrubber, can maintain particulate and gaseous emission levels within current guidelines.

c. SITPA I is a rudimentary system one step above open burning. Although it does attempt to control particulates, the uncontrolled combustion aspects of this technique rule out further development.

d. The SITPA II is a low cost disposal system that could be used at LAP plants located in non-urban and/or low density industrial areas. This technique does include some combustion controls but only removes particulates from the stack gases. There is no attempt to reduce fine particulates or gaseous emissions. Further effort on a feed system is required to obtain safe operation.

e. The wet-air oxidation system has been demonstrated to be a thermally efficient process for disposal of waste propellants. No supplemental fuel is required to maintain the reaction once the system reaches equilibrium. However, the system operates at high pressure (600 - 2200 psig) and requires support equipment (e.g. liquid/solid separators, scrubber) to control the process effluents.

f. A fluidized bed incinerator promises to be the optimum system for the destruction of waste P&E. It is a compact disposal system that can safely destroy the P&E wastes and, through the use of a catalyst, conform to current and anticipated standards for NO_x, HC, and CO without the use of abatement equipment. In addition, the high combustion and operational efficiencies offer high performance with low operational costs.

g. The economic analysis technique developed by MERDC is a viable management decision making tool for choosing the most suitable disposal system for each application.

RECOMMENDATIONS

It is recommended that the SITPA II disposal system be considered for applications requiring the most cost effective system based on present local emission standards. This would particularly apply to LAP plants that have low overall gaseous emissions due to minimal in-plant industrial operations. An additional factor is that most LAP plants are in remote locations away from urbanized industrial areas and therefore have standards that are less stringent.

The current trend is towards stricter air standards, especially in the area of NO_x emissions. This will affect the P&E manufacturing plants that produce acids and utilize them in their manufacturing processes. These plants are usually in urbanized industrial areas due to their requirement for raw materials. Therefore, there will probably be more restrictions on these plants as to the type and quantities of pollutants emitted. Included in these emission limits will be those of the P&E waste incinerator. Therefore, based upon the current economic analyses, the fluidized bed incinerator is the most cost effective system to achieve these goals.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A review of developments in explosive and propellant waste incineration processes is presented which includes a vertical induced draft system, rotary kiln concept, Simplified Incineration Technique for Pollution Abatement (SITPA) I & II, wet air oxidation and the principles of fluidized bed incineration. The advantages and disadvantages of each concept are briefly discussed including efficiency, relative costs, environment effects, flexibility of operation, and safety aspects. The design background and current status of the pilot plant development at Picatinny Arsenal of the fluidized bed system is included.

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